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USE OF STOCHASTIC SIMULATION TO VALUE IMPROVED CROP FORECAST INFORMATION

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ABSTRACT

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Consumer and producer surplus is used with The National Agricultural Policy Simulator (POLYSIM) to estimate the value of improved crop forecast information. For the three supply-demand scenarios evaluated-excess, tight and fluctuating--the net domestic value of improved information is positive ($512 and $73 million) for the latter two situations.

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In 1972, the USSR purchased large quantities of grain before the American public or the U.S. Government was aware of the actual magnitude of the purchases. With commodity prices driven sharply upward, these surprise purchases strongly emphasized the need for more accurate and timely information about foreign crop forecasts. In 1974, the U.S. Department of Agriculture (USDA) began pursuing the possibility of improving foreign crop production (and, therefore, foreign demand) estimates through the use of satellite-derived data (e.g., the Large Area Crop Inventory Experiment [LACIE]. This technology gives promise of a substantial improvement in foreign crop estimation by providing crop condition assessment and early warning of crop production potentials.

Programs to provide information for both public and governmental decision makers are a significant component of many Government agencies. Questions concerning how much information to provide, who benefits from the information, and the value of the information underlie decisions involving the support and management of such programs.

Several previous studies have examined the value of information provided by a specified satellite-based system (Andrews, 1976, 1977; Bradford and Kelejian, 1974, 1977; Heiss; Slaughter). Each study has had some shortcomings in terms of model specifications, implementation errors, and analysis capability for differing policy programs, and forecast accuracy levels under conditions of uncertain yields and export realizations(USDA, Ray and Keith). The present study uses the National Agricultural Policy Simulator (POLYSIM) which accommodates the current agricultural policy structure, is a positivistic model, and simultaneously analyzes seven crops on an annual basis using a block recursive simulation algorithm that allows yields and exports to vary stochastically.

The purpose of this study is to measure the value of improved crop production information resulting from a satellite-based information system. The primary emphasis is on improved estimates of foreign crop production given the high accuracy levels of domestic production forecasts and the difficulty of obtaining highly accurate foreign forecasts. Seven crops are involved in the study: corn, grain sorghum, oats, barley, wheat, soybeans, and cotton.

Methodology

Inaccurate information leads to market distortions, i.e., resources (commodities, capital, labor) are used for tasks that would not have been undertaken or would have been undertaken at a different level if more timely, accurate information had been available for use in planning. The larger the inaccuracies, the larger the distortions. More accurate estimates of foreign crop production would lead to fewer or smaller market distortions and, therefore, more efficient use of resources.

If the additional information allows the decision-making producer to expand (reduce) planned production to take advantage of expected increases (decreases) in product prices, then the value of that information should be the increased revenue obtained from that production response less the added costs. From the consumer viewpoint, information has value if it allows better use of resources, e.g., better timing of purchases to take full advantage of anticipated price changes. For inventory holders, the value of information results from better purchase and sales timing with relation to price changes (Hayami and Peterson, 1972, 1973).

Under the assumption that satellite-based information will be available in a timely enough manner to allow some supply response by producers (and, implicitly, that producers find the new information credible), the measure of the value of the information will be the difference between consumer and producer surplus when the satellite-based information is available and the surpluses when the information is not available to producers and consumers. In this study, foreign production levels are evaluated in terms of export demands for major U.S. commodities which influence domestic production and consumption decisions through their affect on commodity prices. Thus, the analysis requires estimates of final export demand levels and forecasts of exports derived from satellite data.

Since the complete system for developing forecasts from satellite data is not yet in place, it is necessary to simulate the affects of satellite-based information on the performance of U.S. Agricultural markets based on accuracy and timeliness specifications. The stochastic version of POLYSIM (Ray and Richardson) was modified to perform the analysis. For the analysis reported here, final export and yield levels are inputed to represent each of the three scenarios that are discussed later. These export levels are fed into the crop sectors with resulting prices and supply and utilization levels representing the "without satellite information" situation. To depict the with satellite information situation, forecast levels for exports are computed which reflect a specified accuracy relative to the final export levels. Given the specified timeliness of the forecast, production and consumption of each crop are modified in light of the new information. The resulting prices and supply and utilization levels represent the with satellite information case. Consumer and producer surplus measures are then used to compute a numerical value of the forecast information derived from the specified satellite system. The complete procedure is replicated 300 times over a five year analysis period.

The remainder of this section details the procedure for selecting satellite-based export forecasts, how forecast accuracy and timeliness are incorporated into the analysis, and the consumer and produces surplus measures that are used to evaluate the value of the satellite-based information.

Export Forecasts

The forecast value for crop i is drawn from a normal distribution and, on the assumption that the forecast is unbiased, the mean of the distribution is the final export level for crop i. The standard deviation for the distribution is computed to reflect the specified accuracy of the forecast, the exact procedure is discussed in the next section. The general formula for the export forecast for each crop for each of the 300 iterations is given by: Forecast Export Level = Final Export Level + (Standard Deviation x Random Standard Normal Deviate)

Accuracy Specification

The accuracy of the new satellite-based information system is of critical importance. With low accuracies of crop production and export forecasts compared to realized levels, one would expect the information to be of little relative value to U.S. society. Conversely, with high accuracy levels, one would expect the information to have considerable value. The expected accuracy level and associated information value are key considerations for making decisions regarding further investments in satellite-based systems based on "cost/benefit" computations.

In the larger study from which this paper is based, a number of accuracy levels is used in the various analyses. The accuracy level for the results reported here, which corresponds to the "design" accuracy for the system, is to be within 10 percent of the final realized outcome 90 percent of the time (or in nine years out of ten). As indicated earlier, this accuracy level is reflected by the value of the standard deviations used to draw the forecast exports about the means of the final export values. Assuming normally distributed forecast errors, a 90 percent accuracy level in nine out of ten years can be represented as 90 percent of the area ($\pm$ 1.645 standard deviations) under the normal curve between plus and minus 10 percent of the final export value. Letting X be the final export value, then S, the relevant standard deviation, becomes $S = .10X / 1.645$.

Timeliness

The timeliness of the satellite-based crop production forecast has a bearing on the amount of production response that would occur with such an information system. In the production of crops, once the crop is in the ground, little can be done to increase the crop output and the individual farmer has little incentive to destroy a crop to decrease the expected output. Thus, to be of most value to producers, the crop forecast needs to be available prior to planting of a particular crop. It is not expected that all producers will believe the new information from the satellite-based system. Thus, not all producers will base their production decisions on the expected price resulting from the new crop forecast.

The timeliness criterion is entered into the simulation model through the use of weights for the previous year's price and the estimated price. The weighting factors are used to determine the amount of importance the estimated price will have in the producer's price expectations. The more timely the crop forecast, the more producers will base their production decisions on the estimated price. Although other analysis used alternative weights, the results reported in this paper use a 0.90 weight on the simulated price using the crop forecast and a .10 weight on the previous year's final price.

In the model, then, these expected prices, resulting from the weighting of the price estimated using the crop forecast and the price from the previous year, are used to compute the current year's producer supply response. The subsequently calculated value of information may be interpreted as values resulting from forecast accuracy, timeliness and believability.

Consumer Surplus

The consumer surplus resulting from information concerning expected supply or demand levels, given the assumptions of linear curves and parallel shifts in the curves, is measured by one-half the product of the squared equilibrium quantities and the inverse of the slope of the demand curve. For the case of no satellite information for crop i, supply curve S and demand surve D, the consumer surplus resulting from correct information is measured as follows:

$$CS_{ti} = 1/2\ (n_{ti}\ Q_{oti})\ Q_{oti} = 1/2\ n_{ti}\ Q^2_{oti}$$

where CS_{ti} is the consumer surplus for the time period t crop i, resulting from supply curve, S, and demand curve, D_1; n_{ti} is the inverse of the absolute value of the slope of the demand curve for period t; Q_{oti} is the equilibrium quantity for period t, crop i given supply curve, S, and demand curve, D_0.

Similarly for the case with satellite information available consumer surplus is: $CS'_{ti} = 1/2\ n_{ti}\ Q'^{2}_{1ti}$

where Q'_{1ti} is the equilibrium quantity for period t, crop i supply curve S, and demand curve, D_1. The change in consumer surplus (CSC_{ti}) resulting from the satellite information is then: $CSC_{ti} = CS'_{ti} - CS_{ti}$

$$= 1/2\ n_{ti}\ (Q'^{2}_{1ti} - Q^{2}_{oti}).$$

Producer Surplus

The change in producer surplus resulting from satellite-based information, given the assumptions of linear curves and parallel shifts in the curves, can be measured similarly to the change in consumer surplus with the exception of using the inverse of the slope of the supply curve. However, an easier technique is available. Producer surplus can be measured as the gross receipts, price times quantity, minus variable costs which is represented by the area under the supply curve. Therefore, producer surplus is: $PS_{ti} = P_{Oti}\ Q_{oti} - VC_{ti}$;

Where PS_{ti} is producer surplus for time period t, ith crop with no satellite based information; P_{Oti}, Q_{oti}, VC_{ti} are the price, quantity supplied, and variable cost for time t, ith crop, with no satellite based information.

For the case of satellite-based information the producer surplus is: $PS'_{ti} = P'_{1ti}\ Q'_{1ti} - VC'_{ti}$; where each symbol is as defined above, except that the new demand curve is used to determine equilibrium conditions. The change in producer surplus resulting from satellite-based information is measured as the difference between the with information and the without information surplus.

Net Domestic Surplus

Since the commodity demand curve is the sum of the domestic and export demand curves, the resulting consumer surplus is also a sum of the consumer surplus obtained from the domestic demand curve and the consumer surplus resulting from the export demand curve. However, since the objective of this study is to evaluate the effects of improved information on U.S. consumers, only consumer surplus changes resulting from the domestic demand portion of the commodity demand is considered. The production of a commodity is utilized in both the domestic and export markets and, therefore, the producer surplus aspect of this study encompasses both these markets. Thus, the economic surplus from the use of information is the sum of the consumer surplus measured using the domestic demand curve and the producer surplus. For the situation of satellite-based information a similar equation results. The value of the satellite-based information is the difference in the economic surpluses resulting with and without the use of satellite-based information.

Scenarios Evaluated

The three alternative supply-demand scenarios are evaluated: (1) excess supply of crops, (2) tight supply of crops, and (3) fluctuating yields and exports of crops resulting in alternating excess and tight supply situations. These situations are predetermined by selecting the alternative yield and final export values for each crop. Each of these scenarios are evaluated for the years 1979 through 1983 and each is replicated 300 times. The excess supply (increasing ending inventory, decreasing price) scenario is represented by the increase of crop yields by about 4 percent above and the decrease of the crop exports about 14 percent below POLYSIM baseline levels. The reverse is true for the tight supply (decreasing ending inventory, increasing price) scenario. The fluctuating supply-demand scenario starts with excess supply, goes to a tight supply situation, and returns to an excess supply situation.

Results

The value of information estimates for the three supply-demand scenarios are shown in Table I. For the excess supply scenario, the five year average value to consumers resulted primarily from wheat and cotton which both had higher production and lower price levels than under the no additional information assumption. With the fluctuating supply situation, soybeans also contributes positively to the value of the improved crop forecast. Soybeans is the only crop of the seven crops that did

TABLE I

VALUE OF INFORMATION ESTIMATES FOR DOMESTIC CONSUMERS, PRODUCERS,

AND TOTAL FOR THREE SUPPLY-DEMAND SCENARIOS

	1979	1980	1981	1982	1983	5-YEAR AVERAGE
			(Million Dollars)			
EXCESS SUPPLY:						
Domestic Consumer	-73.81	33.40	69.87	31.61	187.67	49.75
Producer	-29.83	7.72	-101.63	-345.74	-348.73	-163.64
Total	-103.64	41.12	-31.76	-314.13	-161.06	-113.89
FLUCTUATING SUPPLY:						
Domestic Consumer	-215.59	794.32	670.26	331.86	284.69	373.11
Producer	245.76	-550.59	-889.96	-145.72	-160.05	-300.11
Total	30.17	243.73	-219.70	186.14	124.64	72.99
TIGHT SUPPLY:						
Domestic Consumer	448.03	179.11	580.94	2187.47	308.94	740.90
Producer	9.21	401.17	-1200.21	-2617.36	2266.72	-228.09
Total	457.24	580.28	-619.27	-429.89	2575.67	512.80

not have a positive value to consumers for the tight supply situation. Soybean production is lower and, consequently, price is higher for this scenario. This is due to crop acreage being shifted away from soybeans to wheat and corn.

Overall, consumers receive a positive value from the improved information regardless of the type of supply-demand scenario, ranging from near $50 million per year to over $740 million per year. Only the consumers in 1979 for the excess and fluctuating supply scenarios received a negative value from the information. The 1979 situation for the fluctuating scenario is an excess supply situation. Wheat, soybeans, and corn are responsible for this result.

Producers, on the other hand, receive a negative value from the improved information. This results from the lower crop prices in general. For the tight supply scenario, the value to wheat and corn producers account for the negative value for the seven crops by more than offsetting the positive value to soybean producers resulting from the higher soybean prices. Wheat and corn producers also account for over 94 percent of the seven crop total with soybean producers receiving a positive value for the fluctuating situation. Six of the seven crops show negative values to the producer under the excess supply scenario. Oat producers, for the five year average, receive $200 thousand more per year from the improved forecast information. For the excess supply scenario, the negative information value to producers more than offsets the positive value to consumers, resulting in nearly $114 million per year loss to the U.S. producers and consumers combined. The net domestic value is negative for each of the seven crops for the excess supply scenario. For the fluctuating supply scenario both consumers and producers of corn and grain sorghum on the average, receive a negative value from the information. For the other five crops the net domestic value is positive. Under the tight supply scenario, the net domestic value for barley and cotton is negative due to large negative producer values. For the fluctuating and tight supply scenarios the value of the improved information to consumers more than offsets the negative values to the producers. Thus, the net domestic value is positive for these two scenarios.

Summary

Consumer and producer surplus is used with the National Agricultural Policy Simulator (POLYSIM) model to estimate the value of improved crop forecast information resulting from the use of a satellite-based crop information system. The crop export forecast is used to estimate expected current year prices. These expected prices are used with the previous year prices to form the producer price expectations on which production decisions are made. Prices and all other endogenous variables are then reestimated. Three scenarios are evaluated: 1) excess commodity supply over the model timeframe; 2) tight commodity over the model timeframe; and 3) fluctuating commodity supply beginning with a commodity excess supply situation.

The results show positive values of the improved information for the consumers in each of the three scenarios. However, for the excess supply situation, the negative value of the information to producers more than offset the positive value to the consumers. For the other two scenarios, the positive value to consumers is larger than the negative value to producers and the net value is positive. The nondiscounted net values averaged over the five years simulated are $113.89 million per year less than the current information system result for the excess supply scenario, $72.99 million per year more than the current information result for the fluctuating scenario, and $512.80 million per year more for the tight supply scenario.

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